Development of Graphite Particles filled Epoxy Resin Composite Material and its Erosive wear Behavior

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***Abstract*— Experiments were carried out to study, impact angle at constant velocity on the solid particle erosion behavior of glass fiber reinforced graphite particles filled in epoxy resin composites. In this work, the various ratio of graphite particles in weigh were reinforced in glass fiber epoxy resin composite laminates were prepared, and then evaluated at different impact angles from 300 to 900 keeping the erodent impact velocity as constant. The erodent used is silica sand with the size varies from 100 – 150 microns of irregular shape. The results were compared with plain epoxy laminate composites. We find that erosive wear rates of glass fiber reinforced graphite particles filled in epoxy resin composites is the lowest. These graphite particles resists fiber matrix debonding. A plain epoxy laminate composite without graphite particle filled shows the highest erosive rate.**

***Keywords*— Epoxy resin, Eglass fiber, Graphite particles, Silica Sand, Impact angles.**

I. Introduction

Polymers and polymer – matrix are becoming increasingly important in applications in which they may be exposed to solid particle erosion. If solid particles impinge against a target surface which cause local damage combined with material removal, this kind of wear referred as erosion [1, 2]. The mechanism of material removal involved in the wear process is determined by the intensity of surface damaging due to repetitive impact events and / or severe scratching of target material. For example, scratching of ceramic surfaces produces either brittle scratches with chip formation by multiple cracking or ductile scratches with Plastic deformation and final rupture or cutting. Surface fatigue and the formation of residual tensile stress during repeated impact on metals have been found to be responsible for the initiation of micro cracks in subsurface layers and subsequent flaking and detachment of small layers [3, 4]. All these mechanisms are not restricted to ceramic or metallic target-materials but may take place under erosion of polymer surfaces as well. Their cumulative occurrence depends, on the testing conditions, in particular the testing temperature, impact angle , type of erodent etc. thus as for materials and other wear situations, erosive wear resistances is not material property but depends strongly on the system in which surfaces function. Schematically this is illustrated in figure.1.

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A brief review on this subject carried out by Walley et al. [5], many of the ductile polymers possess an angular dependence of erosion which is similar to that for ductile metals. On the other hand, may exhibit their highest erosive wear rates at an impact angles of 90^0 [2]. Tilly and Sage [6] showed that various brittle ductile polymer composites under go the same velocity dependence of erosion as metals, namely a power law of $v^{2.3}$, with respect to the size and type of erodent material, two trends can be considered to be valid for harder and / or brittle materials such as metals, ceramics, or epoxies: the erosive wear increases with the hardness of the erodent and the size of the erosive particle size (until a level of saturation is reached in both the cases) [2, 6]. In ductile polymers, however the situations are quite different (i) due their relatively low hardness no pronounced effects of changes in the hardness of the usually much harder erodent materials should expected, and (ii) it has been observed that size effects of the erosive particles only play major role in a diameter range under about 100 μm [6]. Under certain testing conditions, different polymers may exhibit a range of erosion rates spanning more than two orders of magnitude [7] .This must be considered as a clear indications that the wear properties are highly depends on the molecular structures and polymer morphology. For erosive wear tests carried out at room temperature (RT), the following trends of erosion rate as a function of polymer structure can be assumed.

(a) Erosion is higher for polymers with glass transition temperature Ta above RT relative to those with Tg < RT;

(b) For Tg < RT, the wear rate decreases the greater the difference between the experimental temperature and Tg [8];

(c) Erosion is least for low modules, highly elastic rubbers or electrometric polyurethane's.

(d) Amorphous polymers usually erode faster than semi crystalline thermoplastics.

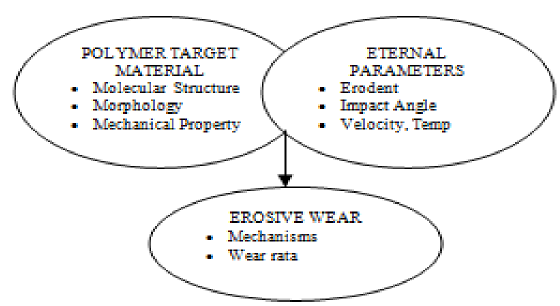

Figure 1.Materials properties and testing parameters which may influence the erosive wear rate results

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In addition, Tilly and sage [6] illustrated that fiber reinforcement can help to reduce erosive wear rate of brittle polymer matrices (such as epoxy (EP)), where as the opposite may occur in the case of a ductile polymer matrix (such as polyamide (PA)). These results are in agreement with those found under sliding

Walley et.al. [5] pointed out that a connection with measurable mechanical properties, as demonstrated successfully by Rather et al. [9] and Lancaster [10] for single-pass abrasion of different polymers, is not easy to transfer to erosion. This is mainly due to the very complex stress state within the target material under erosive impact conditions, the very high strain rates, and possible fatigue mechanisms. Especially it was never found that the erosive wear rate is inversely proportional to the hardness. Although this relationship holds quite well for the erosive wear rate of metals (but only in fewer hardness range), for polymer exactly the opposite trend may takes place. Analyzing the test results presented by Brauer and Kriegel [7] in this respects gives clear evidence for different tendencies. This does not, however, means that the hardness is the mechanical property of polymers which controls their erosive wear behavior. A lower hardness is here only an indication that a greater amount of the impact energy of the erosive particles can be absorbed by elastic deformation of the target surface. Thus a lower amount of the impact energy is available for other mechanisms such as plastic deformation, crack initiation and local fracture. Solid particle erosion of polymers and their composites has not been investigated to the extent that it has for metals or ceramics. Researchers have evaluated the resistance of various types of polymers and their composites to solid particle erosion.

Erosive wear resistance of polymers and their composites is therefore of substantial interest. From literature survey it is evident that very little work has been reported on solid particle erosion studies of epoxy and their composites. Unidirectional reinforced fiber composites represent the basic element of complex composite structure. Therefore, study of their behavior is an important component of the analysis of erosive wear of polymer composites.

Tilly and Sage [6] have also investigated the influence of erosion, their results shows that for the particular materials and conditions of their tests, composite materials generally behave in an ideal brittle fashion, i.e., maximum erosion rate occurs at normal impact. The fracture surface energies of epoxy and polyester resin and their resistance to crack propagation are relatively low. If particulate filler is added to these brittle resins, the particulates inhabit crack growth. As the volume fraction of filler is varied, the fracture energy increases up to a critical volume fraction and then decreases again. Fracture properties of epoxy resin can be improved by addition of other materials. Fillers affect the tensile properties according to their packing characteristics, size and interfacial bonding [11, 14-16]. The maximum volumetric packing fraction of filler reflects the size distribution and shapes of the particles. Srivastava and Shembekar [12] showed that the fracture toughness of epoxy resin could be improved by addition of fly ash particles as filler.

In the present work, experiments were carried out to study the effect of graphite particles filled in different ratios in weight in eglass fiber epoxy resin composites laminates and impact angles at constant velocity of a erodent particle erosion behavior and compared with the plain eglass epoxy resin composites.

II. Experimental details

A. Test Laminate

A curing agent is mixed into the liquid epoxy to polymerize the polymer and to form solid network cross-linked polymer. The type of epoxy resin used in the present investigation is LY956 and hardener HY951. Eglass fiber utilized was reinforced in the above matrix. The graphite particles available are of in size 150 microns. The density of graphite particles is 3.333 g/m3. Epoxy is mixed with the hardener in an appropriate ratio by weight. This epoxy resins and graphite particles are mixed thoroughly in three different proportions 10 wt%, 20wt% and 30wt% respectively. The chop stand E-glass fiber sheet was reinforced in the each of different proportion mixture of epoxy resin and graphite powder. E-glass fiber reinforced graphite particles filled epoxy resin composite laminates were molded at room temperature. The chop stand E-glass fiber reinforced epoxy resin composite laminates were prepared with the mixture of the graphite particles. The laminates were cured at room temperature.

B. Test Setup

Figure 2 shows the schematic diagram of the erosion test rig, which is composed of an air compressor, nozzle, air and particle mixing tube. Compressed air is mixed with the particles. These accelerated particles impact the specimens, which can hold at various angles with respect to the impacting particles using an adjustable sample holder. The particles are driven by a static pressure P. The velocity of the eroding particles is determined using the rotating disc method [13]. The distribution of average particle velocities and mass flow throughout the flow cross section were obtained for several values of pressure P at various distances from the tip nozzle. A pressure of 1 bar is used in erosion testing. The average velocity of silica at this pressure is 24m/s. the specimens were subjected to a particle flow at a given impingement angle. Wear was measured by weight loss after each 60 seconds of erosion. Samples of 20 mm x 20 mm x 5 mm were cut from the composite laminate and mounted in the specimen holder. The condition under which the erosion test were carried out is at room temperature.

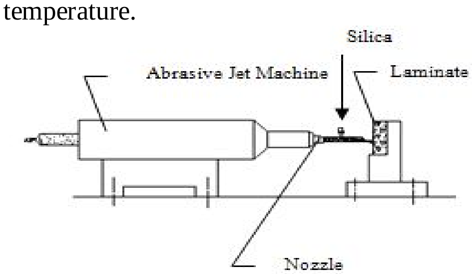

Figure 2. Schematic diagram of erosion test rig

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II. Result and discussions

Figure 3 shows the erosion rates of all the materials as a function of cumulative weight of impinging angles with different impinging angles ranging from 30^0 to 90^0 at velocity of 24 m/s. these plots are obtained by determining the steady state of the weight loss.

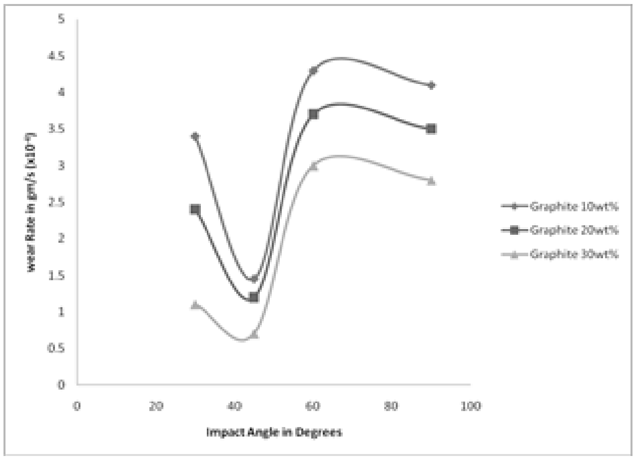

Figure 3. Variation of erosive rate with different impact angles

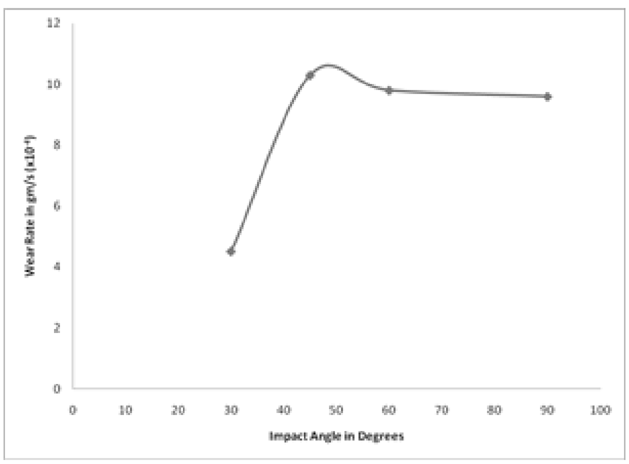

Figure 4. Variation of erosive rate with different impact angles on plain epoxy e-glass laminate

The results indicates that the erosion rate for the composites laminate of Graphite particle filled, as the impact angle increases, the wear increases up to 60^0, further increases in impact angle the wear will decrease. But for epoxy composite as the impact angle increases the wear increases up to certain angle 45^0 further increasing impact angle, wear starts to decrease.

Conclusions

The study of effect of graphite particles as a filler material on the erosive wear rate of E-glass fiber reinforced epoxy resign composite laminates with silica as a erodent at various impingement angles at the velocity of 24 m/s, the following conclusions are drawn:

The influence of Graphite particles as a filler material in epoxy e-glass composite material exhibited wear behavior with a maximum wear at 60^0 impingement angle.

The Graphite particles have a significant influence on the erosive wear of composites. The erosion is higher when the silica sand impacts the composite laminate with out the filler material. The degree of fiber breakage appears to vary with filler material.

The comparison between Graphite particles filled epoxy E-glass composite laminate and plain epoxy E-glass composite laminate shows that the erosive wear rate of plain epoxy E-glass composite laminate is higher than that of Graphite particles filled epoxy E-glass composite laminates. Therefore, observed difference in erosive wear rate behavior of these composite laminates reviles that Graphite particles as a filler material in epoxy E-glass composite laminate resist the formation of crack growth, which improves the resistance of erosive wear rate.

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